Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of Parts 1, 2, 15, 90 and 95 of the Commission's Rules to Permit Radar Services in the 76-81 GHz Band	)	ET Docket No. 15-26
	)	
Amendment of Part 15 of the Commission's Rules to Permit the Operation of Vehicular Radar Services in the 77-78 GHz Band	)	RM-11666
	)	
Amendment of Sections 15.35 and 15.253 of the Commission's Rules Regarding Operation of Radar Systems in the 76-77 GHz Band	)	ET Docket No. 11-90 RM-11555
	)	
Amendment of Section 15.253 of the Commission's Rules to Permit Fixed Use of Radar in the 76-77 GHz Band	)	ET Docket No. 10-28
	)	
Amendment of the Commission's Rules to Permit Radiolocation Operations in the 78-81 GHz Band	)	WT Docket No. 11-202

COMMENTS OF THE NATIONAL ACADEMY OF SCIENCES' COMMITTEE ON RADIO FREQUENCIES

The National Academy of Sciences, through the National Research Council's Committee on Radio Frequencies (hereinafter, CORF[1]), hereby submits its Comments in response to the Commission's February 5, 2015 Notice of Proposed Rulemaking (NPRM) in the above-captioned docket. In these Comments, CORF discusses the nature of observations by the Radio Astronomy Service (RAS) in the 76-81 GHz Band, most of which is allocated on a primary basis to the RAS.

1 See the Appendix for the membership of the Committee on Radio Frequencies.

CORF generally supports the sharing of frequency allocations, where practical, but in enacting rules in this proceeding, the protection of passive scientific observations must be addressed.

I. Introduction: The Role of Radio Astronomy, the Special Vulnerability of Passive Services to Interference, and the Importance of Observations at 76-81 GHz.

CORF has a substantial interest in this proceeding because it represents the interests of the passive scientific users of the radio spectrum, including users of the RAS bands. RAS observers perform extremely important yet vulnerable research.

As the Commission has also long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. The discovery of pulsars by radio astronomers has led to the recognition of a widespread galactic population of rapidly spinning neutron stars with gravitational fields at their surface up to 100 billion times stronger than at Earth's surface. Subsequent radio observations of pulsars have revolutionized our understanding of the physics of neutron stars and have resulted in the only experimental evidence so far for gravitational radiation. Radio astronomy has also enabled the discovery of organic matter and prebiotic molecules outside our solar system, leading to new insights into the potential existence of life elsewhere in our galaxy. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the galaxy, the processes by which stars slowly die, and the complex distribution and evolution of galaxies in the universe. Observation of the enormous energies contained in the enigmatic quasars and radio galaxies discovered by radio astronomers has led to the recognition that galaxies, including our own Milky Way, probably contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Synchronized observations using widely spaced radio telescopes around the world give extraordinary angular resolution, far superior to that which can be obtained using the largest optical telescopes, on the ground or in space.

Radio astronomy measurements led to the discovery of the cosmic microwave background (CMB), the radiation left over from the original Big Bang that has now cooled to only 2.7 K above absolute zero. Later observations revealed the weak temperature fluctuations in the CMB of only one-thousandth of a percent—signatures of tiny density fluctuations in the early universe that were the seeds of the stars and galaxies we know today. The CMB is a unique probe for the ongoing search for gravity waves in the inflationary period of growth after the Big Bang, a particularly active topic in modern astrophysics. Within our own solar system, radio astronomy observations of the Sun have been used for more than half a century to aid in the prediction of terrestrial high-frequency radio propagation.

Since 1974, eight scientists, six of whom are American, have received the Nobel Prize in Physics for their work in radio astronomy.

However, the critical science undertaken by RAS observers cannot be performed without access to interference-free spectrum. Notably, the emissions that radio astronomers receive are extremely weak—a radio telescope receives less than 1 percent of one-billionth of one-billionth of a watt (10^{-20} W) from a typical cosmic object. Because radio astronomy receivers are designed to pick up such remarkably weak signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands, even if those man-made emissions are weak and distant.

In sum, the important science performed by radio astronomers cannot be performed without access to interference-free spectrum. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as a loss of the practical applications from the information learned and the technologies developed.

Of particular concern in this proceeding is the protection of RAS observations at 76-81 GHz. It should be noted that the RAS has primary allocations at 76.0-77.5 and 78-81 GHz, allowing for sampling and analysis of important continuum and spectral line sources.[2] There is a good reason for this primary status: many strong spectral lines are catalogued within this frequency range.[3] Having access to observations of these spectral lines allows astronomers to detect and study deuterated molecules, sulfur dioxide, and long-chain molecules in space, which may have seeded the progenitors of life on this planet.

II. Protection of Radio Astronomy and Specific Proposals in the NPRM.

CORF generally supports the sharing of frequency allocations, where practical. CORF also recognizes the potential safety-of-life benefits and other benefits of some of the proposals in the NPRM. However, protection of the RAS at a limited number of sites can be accomplished while promoting these other uses.

A. <u>"Wingtip" Radar.</u>

The NPRM seeks comments on expanding the use of radar in the 76-77 GHz band to

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[2] The NPRM notes, at paragraph 40, that currently the radio astronomy and space research (space-to-Earth) services are allocated on a secondary basis in the 77.5-78 GHz band. The NPRM asks whether the radio astronomy and space research services also should be upgraded to a primary allocation status in the 77.5-78 GHz band. CORF supports the upgrading of those allocations to primary status. This would add clarity to the need to protect the services, and may also prevent out-of-band harmful interference to those services from transmitters at 77.5-78 GHz.

[3] The frequency line at 80.578 GHz is among those of greatest importance to radio astronomy. *See, Handbook on Radio Astronomy* (ITU Radiocommunications Bureau, 2013) at page 37, Table 3.2. Similarly, the 76-81 GHz band is included in one of the bands preferred for continuum observations. *Id.* at page 35, Table 3.1.

provide for aircraft-mounted radars used while aircraft are on the ground to prevent and/or mitigate the severity of aircraft wing collisions while planes are moving between gates and runways. This application is also referred to as "wingtip" radar.

CORF does not oppose terrestrial use of wingtip radars at airports. Such use may have significant benefits to airlines and ground safety. CORF strongly opposes, however, any aeronautical use of such radars.

Footnote US342 of the Table of Allocations provides that "all practicable steps should be taken to protect the radio astronomy service from harmful interference" in this band, and additionally, it correctly notes that airborne emissions in this band "can be particularly serious sources of interference to the radio astronomy service."[4] An airborne transmitter typically has a free-space range of tens to hundreds of kilometers, even at 76-77 GHz, so it can affect very large areas.

CORF appreciates the FCC's recognition that the service should be provided "only on the ground" and a portion of the FCC's tentative conclusion that there should be an automatic shut-off of the wingtip radar when the plane is in the air (NPRM, paragraphs 58 and 60). CORF remains concerned, however, that the proposal for an automatic shut-off is conditioned on a showing that such a mechanism is "feasible" (NPRM, paragraph 60). This raises the possibility that the radars could be allowed to operate while planes are airborne if an automatic shut-off is not found to be feasible. That would be unnecessary and unacceptable.

In the letter to the FCC that is the basis for the wingtip radar proposal in the NPRM, Honeywell International, Inc. explicitly stated that the radar would only be used for "taxiing aircraft" and that the radar would be used "to avoid ground collisions between aircraft and

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[4] 47 C.F.R. Section 2.106.

between aircraft and stationary objects/service vehicles on **the airport surface (taxiways and ramp areas)**." (emphasis in original).[5] Given Honeywell's request to use this technology only on the ground, there is no need and no rational basis for the Commission to open up the question of using the technology when planes are airborne, especially given the requirements of Footnote US342 and the obvious interference the airborne operation would cause to the RAS, which is a primary service in this band.

Furthermore, while CORF does not have specific expertise in aircraft engineering, it has reason to believe that there is abundant functionality aboard commercial aircraft to identify when a plane is airborne. Similarly, it is CORF's understanding that technology currently exists to switch off radar transmitters, as well as the computer and networking technology to connect such switches to altitude sensors. Thus, CORF urges the FCC to use a critical eye on any claim that such a shut-off mechanism would not be feasible. Beyond the question of technical feasibility, CORF also urges the Commission to use a critical eye in reviewing any claims that an automatic shut off is not economically feasible. In light of the fact that commercial planes can cost more than $300 million,[6] and that the proposed use here is intended to prevent costly accidents to those planes, a small expense to shut off radars when airborne should not be considered economically unfeasible, especially given the likelihood of serious interference to radio astronomy operations from airborne use of those radars.

B. Vehicular Radars.

CORF remains concerned about the impact on radio astronomy observations from the increased use of vehicular radars in the 76-81 GHz band. In paragraph 34 of the NPRM, the Commission seeks comments on the possibility of such interference, possible means of

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[5] Letter of Honeywell International Inc., October 1, 2012, in RM-11555, in attached July 25, 2012 letter to Mr. Bruce Romano, Office of Engineering and Technology, at page 1.

[6] *See, e.g.,* http://www.boeing.com/boeing/commercial/prices/.

mitigating such interference, and the implications of a field test at Kitt Peak, Arizona (*Kitt Peak Study*).[7] The Commission has previously interpreted the results of that field test to assert that factors such as terrain shielding, orientation of the vehicular radar transmitter, and attenuation from placing the radar transmitter behind a bumper, will effectively prevent harmful interference to RAS observatories. This conclusion is incorrect, as shown below.

1. Bumper Issue Is Moot.

The aforementioned bumper-loss question arose only because the car radar supplied for use in the *Kitt Peak Study* was not mounted behind a car bumper during the Study. This issue is now moot, as the Commission's proposed emission limits for radars in the 76-81 GHz band apply outside the bumper, at a distance of 3 meters from the exterior surface of the radiating structure.

2. Vehicle Orientation.

Consideration of vehicle orientation is valid and requires assessment. The applicable Recommendations for protection of the RAS in this case are ITU-R RA.769 and ITU-R RA.1513. They can be very briefly summarized, as follows, for the 76-81 GHz band:

> For an assumed isotropic RAS aperture, 98% of 2000-second observations should be free of interference above either of the following levels:
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> Average over the full RAS band: -129 dBW/m^2
> Highest peak in any 1 MHz: -148 dBW/m^2

It also should be noted that long-range and short-range auto radars (LRR and SRR, respectively) have very different characteristics: LRR has very high antenna gain, rather like car headlights, while SRR provides low gain coverage of the sides and back of the car. LRR has a stronger signal but is much less likely to hit the observatory by chance: about 1 percent for a

[7] National Radio Astronomy Observatory, Electronics Division Technical Note No. 219, "Measurements of Automotive Radar Emissions Received by a Radio Astronomy Observatory," December 8, 2011. Available at http://www.gb.nrao.edu/electronics/edtn/edtn219.pdf.

typical azimuth beam width of 3 to 4 degrees (3.6 degrees is 1 percent of a circle). The elevation beam width is similar and pointed toward the horizon and is assumed to cover the apparent elevation of the observatory, except at very close range. The signals are transient (as long as the car is moving) and will typically fill a small fraction of the 2000-second observation. They are sweeping in frequency and are more likely to exceed the full band rather than the 1 MHz band protection level.

The Commission's proposal sets the following limits: average and peak emission limits for radars in the 76-81 GHz band could not exceed 88 μWcm^2 and 279 μW/cm^2, respectively, measured at a distance of 3 meters from the exterior surface of the radiating structure, without distinguishing between LRR and SRR.

A single long-range car radar operating at these emission limits will produce -92.5 dBW/m^2 at a distance of 10 kilometers, assuming 0.15 dB/km atmospheric attenuation (per ITU-R P.676) and 1% illumination time (20 seconds during a 2000-second integration):

Average emission 88 μWcm^2 at 3 meters:	-40.5 dBW/cm^2
Per square meter gives an increase of 40 dB:	-0.5 dBW/m^2
At a range of 10 km this is reduced by $(10,000 / 3)^2 = -70.5$ dB:	-71.0 dBW/m^2
Allowing 1% illumination time, -20 dB:	-91.0 dBW/m^2
Atmospheric absorption 0.15 dB/km for 10 km, -1.5 dB:	-92.5 dBW/m^2

This radar signal is thus 36.5 dB (that is, <u>almost 5,000 times</u>) stronger than the -129 dBW/ m^2 level needed to protect the RAS.

3. The Problem of Cumulative Interference.

Unfortunately, it also appears that the Commission has ignored the issue of cumulative interference from multiple auto radars. For example, while the Commission has quoted language from page 10 of the *Kitt Peak Study* regarding potential mitigating factors, such as terrain shielding, which could reduce the radius of a protective zone around an RAS facility (the avoidance zone), the sentence before that states that for "multiple transmitters on a given vehicle, and for more than one vehicle in view of the telescope, the avoidance zone radius would be correspondingly increased." Similarly, in a 2004 paper sponsored by the European Conference of Postal and Telecommunications Administrations (CEPT), the impact of 79 GHz radars on radio astronomy and other incumbent services in that band was studied. In Annex C, after extensive calculations, the paper concludes: "The technical feasibility of co-existence between automotive collision warning SRR and the RAS service in the frequency band around 79 GHz is dependent on the aggregated impact of SRR devices transmitting in the direction of a RAS station. From the results based on the model used, with a maximum e.i.r.p. of -3 dBm/MHz per SRR device around 79 GHz, it is concluded that regulatory measures (e.g., automatic deactivation mechanism close to RAS observatory stations) are necessary to enable the co-existence between SRR and the RAS service."[8]

4. Mitigating Harmful Interference.

In sum, the calculation above, in agreement with the *Kitt Peak Study,* demonstrates that vehicular radars would have a significant negative impact on radio astronomy observations in the

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[8] CEPT ECC Report 56, *Compatibility of Automotive Collision Warning Short Range Radar Operating at 79 GHz with Radiocommunications Services* (Stockholm, October 2004).

76-81 GHz band. In the absence of substantial terrain shielding, evaluated on a case by case basis, control of the radar transmitter will be needed.[9]

Nevertheless, CORF is mindful of the potential safety benefits of enhanced vehicular radars. There are a number of different ways in which the harmful impact of vehicular radars on RAS observations could be limited without significantly reducing the safety benefits of the radars. First, the Commission could require that the radar transmitters be automatically turned off within a limited radius around RAS observatories, through use of Global Positioning System functionality in the vehicles. This would have a very small impact nationwide because there are only a few facilities in the United States that currently observe in the 76-81 GHz band: the Arizona Radio Observatory, with facilities on Kitt Peak; and the National Radio Astronomy Observatory at Green Bank, West Virginia.[10] At the very least, the Commission should require that vehicles with these radars have a manual on/off switch that could be used by the driver in response to signs posted on or near these observatories.

C. Fixed Radars.

The NPRM (at para. 48) seeks comments on the proposal to regulate airport foreign object debris (FOD) radars under Part 95 of the Commission's rules, in place of regulation under Part 15 or Part 90. CORF has less concern about interference from fixed operations than from mobile operations. Fixed operations are easier to identify if they are causing interference, and if necessary, the operator can be contacted to remedy the problem. The core question is how to ensure that the operator has an incentive to share the band well and limit interference to other users. If radar operators are authorized under Part 15, they have the obligation to prevent

[9] Furthermore, as shown in CORF's August 8, 2011 Comments in this proceeding, fencing or other artificial local shielding is not a practical (or likely even possible) solution. *See* page 5 and Appendix B of those Comments.

[10] The facilities at Kitt Peak may be moved to Mt. Graham in Arizona at some point in the future.

harmful interference to other users in a primary allocation, such as radio astronomy, or the Part 15 operator could lose its authority to operate. Similarly, airport FOD radar operators authorized under Part 90 that have the potential to interfere with nearby RAS facilities are required to have their operations coordinated through the Interdepartment Radio Advisory Committee (IRAC). With the proposal to regulate all fixed radar operations in the band (airport FOD and others) under Part 95, fixed radar operators would neither have to coordinate through IRAC, nor would they be subject to termination due to secondary status. CORF is concerned that the removal of these regulatory requirements would make it more difficult for a radar operator to find parties with whom it would interfere and could also create disincentives for operators in this band to be good spectral neighbors. CORF suggests that a solution would be a coordination procedure for fixed operations, with the least possible burden. Specifically, the Commission should consider requiring use of the automated "red-light/yellow-light" mechanism currently used for licensing of fixed point-to-point links at 71-95 GHz,[11] or a similar mechanism.

III. Conclusion.

CORF generally supports the sharing of frequency allocations, where practical. CORF recognizes the potential benefits of the radar uses proposed in this proceeding. Nevertheless, in light of the primary allocations to RAS and the ease with which radars could cause interference to radio astronomy observations in this band, protection of radio astronomy must be addressed in this proceeding and can be accomplished with little or no significant burden on the radar users.

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[11] *See,* Wireless Telecommunications Bureau Announces Permanent Process for Registering Links in the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands, *Public Notice*, DA 05-311 (rel. February 3, 2005). The Commission has found that in regards to such procedures, "the costs of performing interference analyses would be small, particularly when compared to the benefits of preventing harmful interference to existing operations." *See,* In the Matter of Allocations and Service Rules for the 71-76 GHz, 81-86 GHz, and 92-95 GHz Bands, *Memorandum Opinion and Order,* FCC 05-45 at para. 11 (rel. March 3, 2005).

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

By: Ralph J. Cicerone

Ralph J. Cicerone
President, National Academy of Sciences

Direct correspondence to:

Committee on Radio Frequencies
Keck Center of the National Academies
500 Fifth Street, NW, Room 954
Washington, DC 20001
(202) 334-3520

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Date

Appendix

Committee on Radio Frequencies

Members

Jasmeet Judge, *Chair*, University of Florida
Liese van Zee, *Vice Chair*, Indiana University
William Blackwell, MIT Lincoln Laboratory
Todd Gaier, Jet Propulsion Laboratory
Kenneth Jezek, The Ohio State University
Kenneth Kellermann, National Radio Astronomy Observatory
David Le Vine, NASA Goddard Space Flight Center
Amy Lovell, Agnes Scott College
Timothy Pearson, California Institute of Technology
Paul Siqueira, University of Massachusetts, Amherst
Gregory Taylor, University of New Mexico
Thomas Wilson, Naval Research Laboratory

Consultants

Michael Davis, SETI Institute, retired, Consultant
Darrel Emerson, National Radio Astronomy Observatory, retired, Consultant
Paul Feldman, Fletcher, Heald, and Hildreth, Consultant